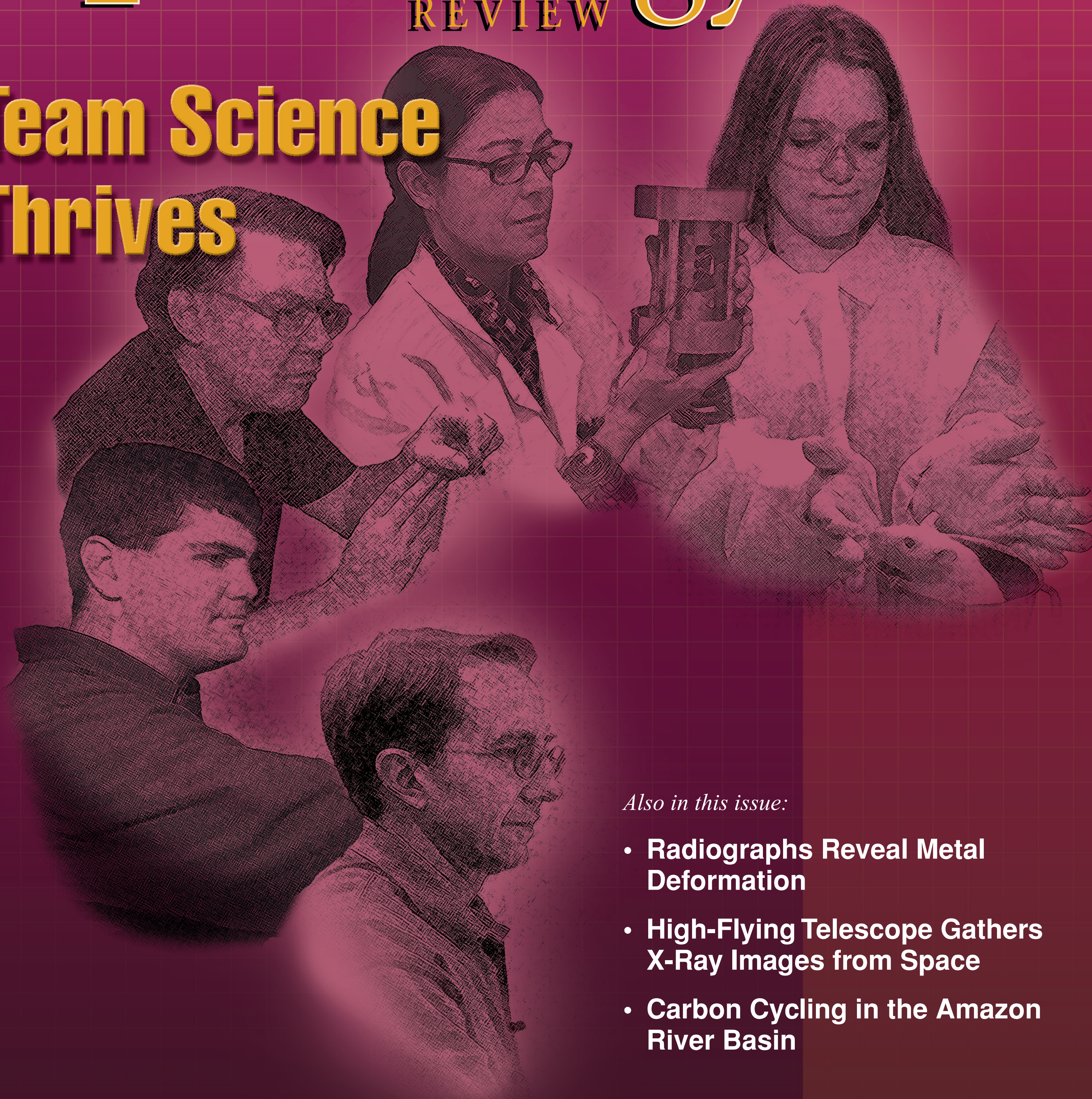
March 2006

Science & Technology REVIEW

National Nuclear Security Administration's
Lawrence Livermore National Laboratory

Team Science Thrives

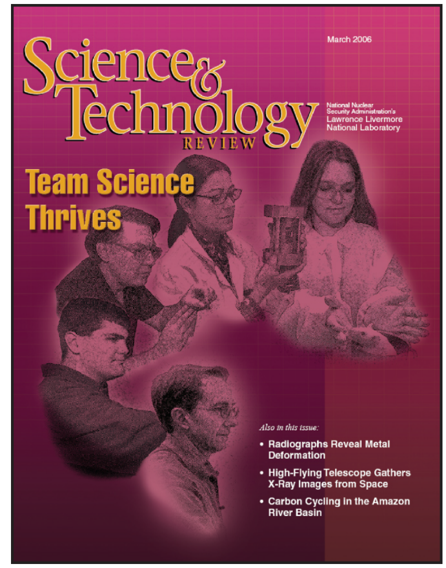


Also in this issue:

- Radiographs Reveal Metal Deformation
- High-Flying Telescope Gathers X-Ray Images from Space
- Carbon Cycling in the Amazon River Basin

About the Cover

Technicians are significant contributors to Lawrence Livermore's atmosphere of "passion for mission" and technical innovation. The article beginning on p. 4 features five technicians whose work exemplifies the important contributions of Livermore's technicians (clockwise from bottom on the cover): Rod Saunders, Adam Bertsch, Carl Boro, Lisa Lauderbach, and Jennifer Montgomery. The Laboratory provides a wealth of career opportunities for technicians, and they, in turn, play a key role in the team science essential to the Laboratory's success.



Cover design: Daniel Moore, Photographer: Michael Anthony

About the Review

Lawrence Livermore National Laboratory is operated by the University of California for the Department of Energy's National Nuclear Security Administration. At Livermore, we focus science and technology on ensuring our nation's security. We also apply that expertise to solve other important national problems in energy, bioscience, and the environment. *Science & Technology Review* is published 10 times a year to communicate, to a broad audience, the Laboratory's scientific and technological accomplishments in fulfilling its primary missions. The publication's goal is to help readers understand these accomplishments and appreciate their value to the individual citizen, the nation, and the world.

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National Nuclear Security Administration

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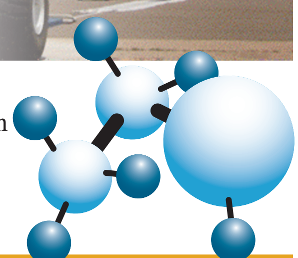
Features

Research Highlights



Departments

New way to fight cancer revealed

Researchers from the Laboratory and the University of California at Davis Cancer Center have unveiled a reliable technique to characterize the binding interaction of multivalent molecules designed for targeted drug delivery in cancer treatment. The team used atomic force microscopy to measure the binding forces between several single-chain antibody fragments and Mucin1 peptide. Large quantities of Mucin1 are commonly found in a variety of human epithelial cells, and one of its forms is a characteristic marker for prostate, breast, colon, lung, gastric, and pancreatic cancers. Binding between antibodies that recognize the marker and Mucin1 is critical to targeted drug delivery for cancer patients.

Not only does the technique aid doctors in treating cancer, but it also may benefit the Laboratory's efforts in evaluating antibodies and designing better binding molecules for biosensors that have a critical role in national security. The team's research appeared in the November 3, 2005, edition of the *Proceedings of the National Academy of Sciences.*

Contact: Todd A. Sulchek (925) 422-2798 (sulchek1@llnl.gov).

Model shows stars form by gravitational collapse

Researchers from the Laboratory, the University of California at Berkeley, and Princeton University have concluded that the generally accepted competitive accretion model of star formation cannot explain what astronomers observe of star-forming regions studied to date. Their findings appeared in the November 17, 2005, edition of *Nature*. Through a series of theoretical calculations and supercomputer simulations, the team determined that new stars form by gravitational collapse rather than the widely held belief that they come from the buildup of unbound gas.

The model used by the team simulates the complicated dynamics of gas inside a swirling, turbulent cloud of molecular hydrogen as it accretes onto a star. This study is the first to determine the effects of turbulence on the rate at which a star accretes matter as it moves through a gas cloud. In the competitive accretion model, clumps in hydrogen gas clouds form into cores. These cores are the seeds that grow to become stars. The researchers' model, often termed the gravitational collapse and fragmentation theory, also presumes that clouds develop clumps in which protostellar cores form. However, the cores are large and, although they may fragment into smaller pieces to form binary or multiple star systems, contain nearly all the mass they ever will. The work was supported by the National Aeronautics and Space Administration, the National Science Foundation, and the Department of Energy.

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Protein folding may lend clue to risk factor genes

Ted Laurence of the Laboratory's Physical and Biosciences Institute, along with collaborators from the University of California at Los Angeles, measured varying distances within single protein molecules to understand the process of protein folding. The recent study sheds some light on what causes a protein to go from a folded to unfolded state. Protein folding gone awry may be a key factor in determining why certain people are prone to Alzheimer's and other neurodegenerative diseases. In addition, understanding how and why a protein folds can help scientists design proteins to perform specific tasks.

Using a technique called fluorescence resonance energy transfer, the team measured distances between two specific points on a protein. Special fluorescent chemical groups—a donor and an acceptor—are attached to those points. If the donor and acceptor are within 8 to 10 nanometers apart, the energy transfer occurs. "The structure of the energy landscape is what encourages the protein to fold or not to fold," says Laurence. "We want to see what a protein is doing in an unfolded state and why it folds. Then we can understand why the folding sometimes goes wrong." The team's research appears in the November 29, 2006, edition of the *Proceedings of the National Academy of Sciences.*

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Scientists get precise measure of a basic theory

Laboratory researchers have made a new measurement that is 10 times more precise than recent measurements to test quantum electrodynamics (QED)—an extension of quantum mechanics. The scientists entered a new realm in the search for QED deviations by measuring light generated in the extreme electric fields surrounding the nucleus of uranium. Deviations would have far-reaching consequences for understanding the universe because it would indicate that QED is not a fundamental theory of nature.

The team tested the theory using Livermore's SuperEBIT, an electron-beam ion trap, to strip uranium of all but three electrons, forming a uranium plasma. Using high-resolution spectrometers in the experiments, the researchers were the first to look directly at the light emitted by the uranium plasma. The high precision of the SuperEBIT measurements allowed the team to extract an experimental value for the new QED effects, in which the polarized vacuum and the self-energy interacted with each other and themselves. Previous measurements only tested the noninteracting manifestations of QED. The team's results appeared in the December 2, 2005, edition of *Physical Review Letters.*

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Without Fanfare, Technicians Safely Keep the Laboratory Humming

ERNEST O. Lawrence, the Laboratory's cofounder, invented the cyclotron, or atom smasher, while he was a physics professor at the University of California (UC). The cyclotron made possible an era of high-energy physics that saw the disintegration of atomic nuclei and the creation of new elements.

Like other universities, UC was not known for building large pieces of research equipment. To efficiently build increasingly larger cyclotrons, Lawrence formed multidisciplinary teams comprising physicists, chemists, engineers, technicians, and other specialists. The multidisciplinary approach was quite novel but very successful.

Lawrence used the same multidisciplinary approach to build one of the premier centers of applied research and engineering at Livermore. Unlike universities, Lawrence Livermore is not built around disciplines such as chemistry, math, and physics. Instead, we draw experts from different disciplines depending on the research project, and members of a team shift to new projects as needs change. This approach to research is one of Lawrence's major legacies, and it is working superbly 54 years after the Laboratory's founding.

Technicians, or techs, are essential members of every team, from building anthrax detectors to constructing tiny targets for the National Ignition Facility. The article beginning on p. 4 honors their roles and describes the contributions of five techs from the Energy and Environment, Chemistry and Materials Science, National Ignition Facility Programs, Biosciences, and Computation directorates. Techs are a vital part of other directorates as well, including Defense and Nuclear Technologies.

In forming multidisciplinary teams, we strive for the right balance of researchers. In general, we have a large number of techs working with many engineers and a small group of Ph.D. scientists, who are often striving to realize the ideas of a few theorists. Although scientists tend to receive the limelight, few ever build anything. Techs, however, are expert in electronic, pneumatic, hydraulic, mechanical, laser, and explosive systems, and they are exceptionally talented at working with their hands. A scientist conceived of a handheld detector for anthrax and other airborne diseases, but techs made it a reality.

The requirements for being a Livermore tech include intellectual curiosity, technical smarts, and a desire to learn. We have some of the world's best techs because they know their stuff, and they know that what they do matters to the nation. Unlike techs at other places, Livermore techs are not involved in production work; they do different things all the time, and every new project is a challenge. Sometimes they don't know what they'll be doing next week, but they are certain it will be new and challenging.

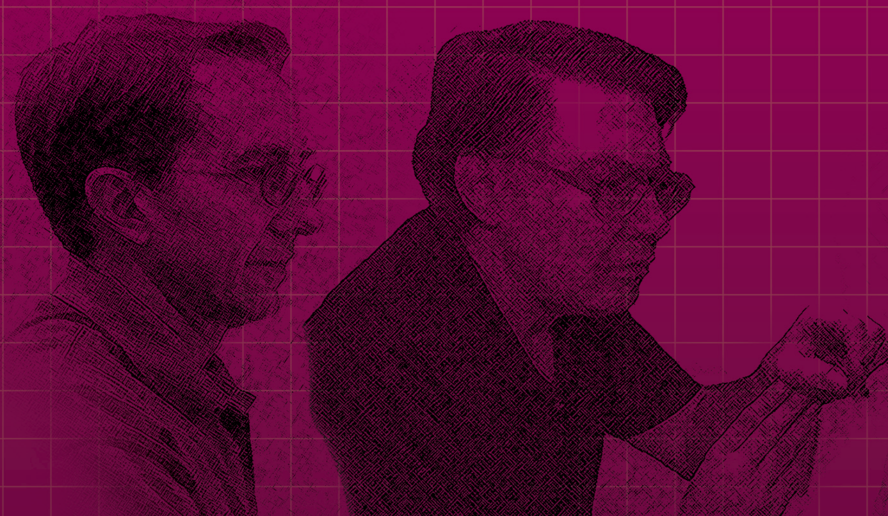
Techs are dedicated to safety. We have assignments that involve hazardous materials and equipment, and safety is paramount around high explosives, high voltages, special nuclear materials, high laser fluences, and other environments. Some techs work under difficult conditions such as the Contained Firing Facility at Site 300, where high explosives are tested in a completely contained environment. Following a test, techs reenter the facility in uncomfortable personal protection equipment to retrieve experimental data and begin cleanup. The techs know what can safely be made more efficient. They have recently halved the time it takes to turn the facility around for another test while observing the strictest safety standards.

The techs in our Superblock handle extremely challenging materials such as plutonium. They turn out exquisite parts under daunting high-security conditions. These techs must undergo thorough inspection on entering and exiting their facility. I salute their professionalism.

In another example, techs at the Decontamination and Waste Treatment Facility move radioactive wastes off site. It's a difficult job, and techs work under an enormous amount of scrutiny from state and federal agencies. These people keep us functioning and safe, and they do their jobs without a lot of fanfare.

Techs make it happen. We wouldn't have a successful laboratory without them.

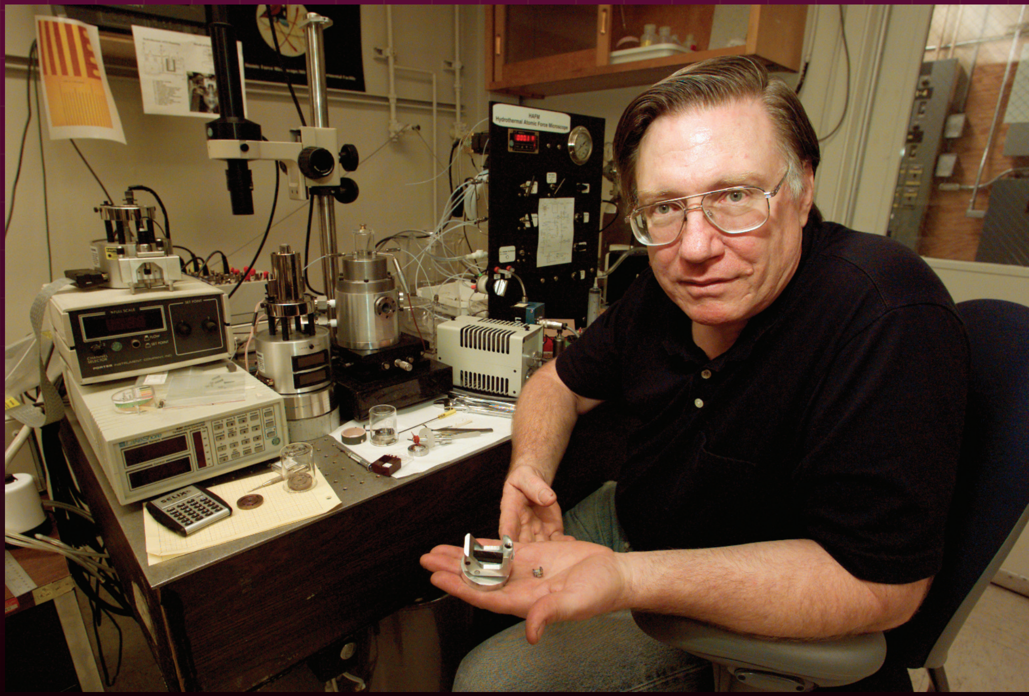
■ Bruce T. Goodwin is associate director for Defense and Nuclear Technologies.



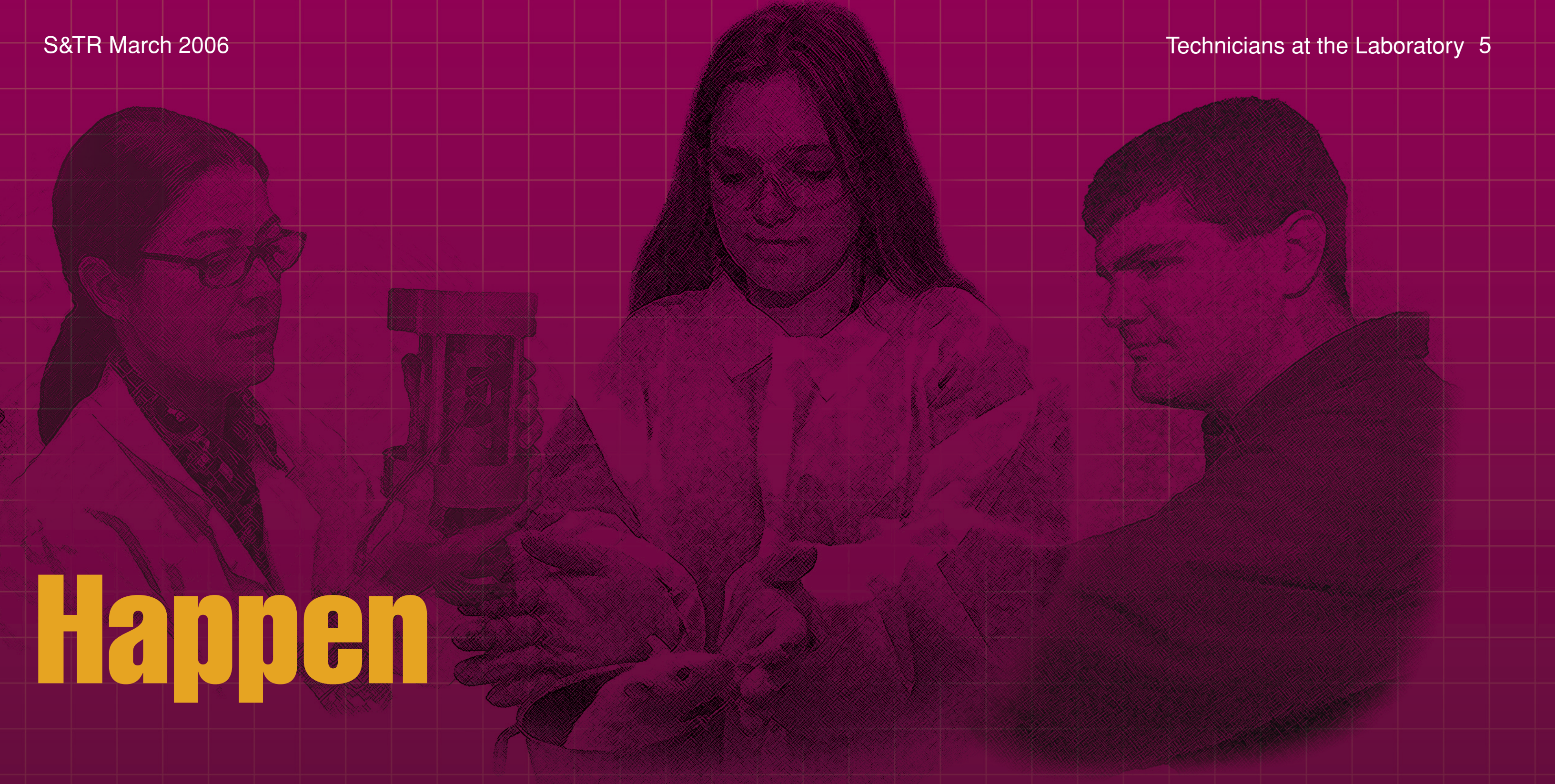
These People Make Things

Rarely in the limelight, technicians at Lawrence Livermore are essential to successful research projects.

ERNEST O. Lawrence, the Laboratory's namesake, pioneered the concept of team science, in which experts from different disciplines combine efforts to tackle challenging problems in science and national security. Most Livermore research projects have people on the team who often work behind the scenes to "make things happen." Known as technicians, technical specialists, scientific associates,



Carl Boro has a reputation for being able to build any kind of part for geophysics experiments.



Happen

and other terms, these men and women comprise more than 20 percent of Lawrence Livermore's workforce of 8,000 employees.

Technicians typically have an associate's or bachelor's degree and work alongside scientists with more advanced degrees. Their work is essential; however, technicians can be overshadowed by principal investigators and lead researchers. Nevertheless, "techs" contribute significantly to technical innovation at Livermore. In their various assignments, they accumulate a wealth of knowledge about how to build a part, run an experiment, design an instrument, or calibrate a device, skills that often come from experience outside formal education.

The important contributions of techs are exemplified by five profiles: a scientific instrument maker, a high-explosives "ramrod," a shot operator for the world's most powerful laser, a bioresearcher of pathogenic bacteria, and a systems administrator for the world's most powerful computer. As their stories show, they have a passion for the Laboratory's mission, and they are part of the outstanding, dedicated teams that, in Director Mike Anastasio's words, are "the key to Livermore's enduring success."

Boro Can Make It

After graduating with a bachelor's degree in industrial studies, Carl Boro considered a job as a high school shop teacher. Instead, he decided to join the Laboratory so he could use his skills in pursuing research done at few other places.

Even after 28 years at the Laboratory, says Boro, "I keep discovering I can stretch my limits." But he cautions that this success comes with a hidden danger. "When you've done the nearly impossible, the next time around, they want you to do the impossible."

Boro is a senior engineer technical associate in the Experimental Geophysics Group within the Energy and Environment Directorate. The group conducts laboratory experiments to measure the physical and chemical properties of materials, mineral and rock physics, chemical transport, and mechanics of rocks and fractures. The group also focuses on laboratory measurements related to underground imaging and material behavior under high pressures using diamond anvil cells and other experimental apparatus.

Boro designs and manufactures one-of-a-kind parts and instruments for these geophysics experiments. According to scientist Brian Bonner, "If we can't buy it, Carl will make it."

"People come to me with an idea for an experiment," says Boro. "I ask them to tell me what they're trying to accomplish."

Bonner says, "I used to come in with a sketch and dimensions for a new instrument. Now, we discuss what the project entails. By the time I'm finished talking with Carl, I've got something different, but better."

Boro has replaced the drafting table, paper, and pencil he once used to draw proposed parts with computer software. Most of his shop tools, however, have remained the same: mills, lathes, a surface grinder with diamond wheels, welding equipment, saws, and micrometers. He occasionally sends work to specialists within the Laboratory, such as laser welders and techs in the water jet shop, or to outside vendors.

Because experiments are always changing, "I do a little of everything," he says. "There's always something new." Boro once built a nonmagnetic instrument for an experiment at the Nevada Test Site. The instrument featured two 7-meter-long booms that rotated around a nonmagnetic turntable. He also designed a device that measures how much seismic energy is absorbed by an earthen material.

For another assignment, he designed and built a device to hold an evacuated, 1-meter-diameter glass sphere as it was lowered from a research ship to a predetermined depth underwater. When the sphere is imploded, it generates an acoustic signal that can be used to calibrate instruments for verifying nuclear treaties.

Boro recently completed tiny parts for the hydrothermal atomic force microscope, which was built at Livermore. It is used to study crack growth in minerals. The microscope, which earned Boro four patents, allows an experimenter for the first time to control pressure and temperature and image samples as they are being bent. The bending jig is less than 10 millimeters in diameter.

"The scientists knew what they wanted to measure but weren't sure how to accomplish it," he says. Boro first built a model five times larger than the final parts so he could more easily determine what was feasible. The machined parts, made of titanium and sapphire, use a tiny set screw to bend the sample. Boro machined a 1.7-millimeter nickle alloy set screw of 127 threads per inch because he couldn't find one to purchase.

Boro's efforts have not gone unnoticed. He was part of the team that won a 2003 Lawrence Livermore Science and Technology Award for experiments on the equation of state of plutonium. He was also on the team that won a 1997 R&D 100 Award from *R&D Magazine* for the oil-field tiltmeter. An array of these instruments is used to monitor oil-well hydrofracturing, a technique for cracking deeply buried rock to provide channels through which oil can flow. (See *S&TR*, October 1997, pp. 4–5.)

Lisa Lauderbach prepares a sample of energetic material for testing in the Laboratory's High Explosives Application Facility.

An Explosive Career

Following her natural bent to understand how things work, Lisa Lauderbach graduated from San Joaquin Delta College with an associate of arts degree in mechanical engineering technology. "At Delta College, I learned there are real jobs for people with skills like mine," she says. Two of her instructors were part-time Livermore employees, and they encouraged her to apply at the Laboratory.

For more than a decade, Lauderbach has worked at the High Explosives Application Facility (HEAF), a center for developing and testing energetic materials. She was recently promoted to another position in which she uses her knowledge of mechanical technology.

Working closely with mechanical engineer Bruce Cunningham and chemist Raul Garza, Lauderbach specializes in two areas of energetic materials research: mechanical properties testing and explosives testing. Together, these tests provide valuable data on an energetic material's mechanical, performance, and safety characteristics.

Mechanical properties tests involve subjecting an explosive to various loads and temperatures to help predict its performance even after long periods of storage. In experiments that can last from seconds to weeks, Lauderbach looks for obvious changes, such as large cracks, and the hard-to-detect, such as 1 micrometer of movement in a long-term "creep test." She also helps design and fabricate parts for testing instruments. For example, one machine she worked on alternates between tensile (pulling) and compressive (squeezing) stresses to investigate a material's response to repeated cyclic loading.

Lauderbach works at a control panel in a laboratory protected by concentric walls of reinforced concrete for safety. From there, she runs mechanical properties tests, analyzes the resulting data, and writes reports to the principal investigators.

On the explosives tests, Lauderbach is known as an experimental "ramrod." In this capacity, she schedules and designs a shot, fields diagnostics, analyzes data, and reports the results. Explosives tests help determine a material's performance and safety characteristics. HEAF is designed to test up to 10 kilograms of TNT-equivalent in specially designed containment vessels. Shots with explosives are typically preceded by one or two dry runs, and tests are conducted by specialized technicians.

Explosives tests use several diagnostics, including high-speed optics and timing pins. The multibeam Fabry–Perot velocimeter, a diagnostic designed by Livermore scientists, provides high-resolution continuous velocity data about materials traveling up to 3,000 meters per second. Most of these experiments are part of research for the National Nuclear Security Administration's (NNSA's) Stockpile Stewardship Program, but Lauderbach has also conducted tests on explosive materials for the Federal Bureau of Investigation and the Department of Homeland Security. "Conducting explosives experiments is challenging work," she says.

Lauderbach started at Livermore in the Engineering Directorate as a mechanical technician assigned to Site 300, the Laboratory's research facility for large-scale high-explosives (HE) processing and testing. She supported HE operations by designing, fabricating, and installing mechanical parts and systems, learning from people who had decades of experience working safely around HE. Eventually, she supported hydrodynamics tests, which are used in stockpile stewardship research to measure the hydrodynamic characteristics of metals as they are detonated.

Transferring from Site 300 to Livermore's site, Lauderbach joined the Environmental Protection Department's Radioactive and Hazardous Waste Management Division. She supported nine Livermore facilities, including the Superblock (where special nuclear materials are stored), Biosciences Directorate, and HEAF. Because of her experience working with energetic materials and hazardous waste, she became the lead environment, safety, and health specialist for HEAF. In this position, she manages the containment and disposal of energetic materials waste for Livermore's main site.

Lauderbach has returned to Delta College to share with students her experiences at Livermore. She appreciates the opportunity to give back to the college and discuss her career because, she says, "People at the Laboratory have been extremely generous with their knowledge."

As lead operator for the National Ignition Facility, Rod Saunders is expert in orchestrating a laser shot.

On the Laser's Edge

When Rod Saunders arrived at the Laboratory with an associate of arts degree in electronics, he looked forward to a career in the same field. "I thought my job would be all electronics." Instead, Saunders was quickly recruited to join Livermore's laser effort to build increasingly powerful lasers composed of thousands of optical components. "A series of doors opened up for me," he says, "many of them unexpected."

Some 34 years later, Saunders is lead operator for the National Ignition Facility (NIF), the most powerful laser in the world. He also has become one of the

Jennifer Montgomery investigates the proteins manufactured by *Yersinia pestis*, the bacterium causing plague.

Laboratory's best resources for building and testing optical diagnostics and orchestrating a NIF shot.

Saunders has worked on several generations of Livermore lasers, including Argus, Shiva, Novette, Nova, and finally NIF. On Shiva, he learned to align laser beams and minuscule targets. For Novette and the 10-beam Nova laser, he built many electro-optical sensors, which are used to characterize the laser beam. Saunders eventually joined the Nova shot operations staff and became shot director, a position he held for 14 years.

During the NIF construction in the late 1990s and early 2000s, he built some of the first sensors for the giant laser. With his extensive experience as a shot operator, he was chosen as one of four shot operators for NIF and then was named lead operator. In this role, he participated in the NIF Early Light campaign, a series of experiments designed to test NIF components using beams from the first four completed lasers. By the end of the campaign, in October 2004, more than 400 shots had been performed, and NIF had demonstrated its capability to deliver high-quality laser beams to the target chamber.

Saunders usually can be found in the NIF control room, which is modeled after the National Aeronautics and Space Administration's mission control room in Houston, Texas. NIF control room operators, most of them technicians, access data through a hierarchy of on-screen graphics menus. The data shown correspond to thousands of control points for electronic, optical, and mechanical devices, such as motorized mirrors and lenses, energy and power sensors, video cameras, laser amplifiers, and diagnostic instruments. Operators can also view videos of key hardware from cameras located throughout the complex.

Saunders is part of a team that is diagnosing laser light from the first bundle of eight NIF laser beams. These so-called laser science shots examine laser beam quality, shape, and energy. For the tests, the laser light terminates in calorimeters instead of targets in the NIF target chambers.

"Conducting shots on NIF is a real team effort," Saunders says. As lead shot operator, he works with the NIF shot director, usually a Ph.D. physicist with a laser science background. He is in radio contact with other technicians in the control room and at stations throughout the facility. He typically works from 3 p.m. to 1 a.m.; shots are run only on swing shift.

In the control room, his main task is coordinating all 14 NIF subsystems as part of a three-and-a-half-hour shot countdown for the laser science shots. Shots involving the target chamber require even longer setup times. The countdown checklist has moved from a manual process to a nearly automated one. Saunders also serves as chair for the committee that reviews proposed changes to the checklist. (See *S&TR*, July/August 2005, pp. 4–12.)

The combination of overseeing thousands of laser shots and building hundreds of sensors has given Saunders an intimate knowledge of many NIF subsystems and the possible pitfalls of designing and executing a laser shot. "To have a successful shot, we have to understand what all the subsystems do and how they all have to work together," he says.

Front Lines of Biodefense

Researchers in Livermore's Biosciences Directorate are on the front lines of fighting cancer and detecting bioterrorism, where they combine advanced instrumentation with the latest understanding of the structure and function of cells and viruses. Jennifer Montgomery joined this effort 4 years ago after graduating with an associate of arts degree in natural sciences from San Joaquin Delta College.

Montgomery had planned to go to nursing school and took courses in biology, microbiology, and physiology. However, her husband's parents both worked at Livermore and suggested she apply. "I was hired in part because of my experience with animals," she says. Indeed, growing up in California's Central Valley, she raised sheep, pigs, steers, and heifers as a member of Future Farmers of America.

Montgomery joined a Livermore team studying the effects of complementary and alternative medicines, an effort supported by the University of California Breast Cancer Research Program. Many cancer patients and survivors self-administer complementary and alternative medicines in an effort to augment conventional treatments, improve health, or prevent recurrence. Herbal tonics often become popular with breast-cancer patients because anecdotal evidence indicates the tonics can treat or prevent the disease. "The herbs used to make the tonics that we studied are important in Asian medicine," says Montgomery, "but little information was available about their safety, efficacy, and potential reactions with prescription drugs."

In this project, Montgomery studied laboratory rats that had been exposed to the carcinogen dimethyl benzanthracene (DMBA) to induce mammary tumors. She administered a tonic containing eight herbs orally to one group of rats. A control group was not fed the tonic. After 23 weeks, the animals were euthanized, and their mammary tissues analyzed. Counter to expectations, the results showed that ingesting the tonics promoted the growth of existing tumors and induced the formation of new tumors, compared with tumor growth in the control group.

Montgomery also studied the effects of the herbal tonic on human breast-cancer cells. This research indicated that the tonic activates estrogen receptors, thereby increasing proliferation of breast-cancer cells. Montgomery presented a poster on the group's findings at a conference of the American Association for Cancer Research.

She notes that many state and federal regulations address the treatment of animals used in medical research. In addition, Livermore's Animal Care and Use Committee oversees Laboratory research involving animals. Montgomery credits people in Livermore's Animal Care Facility for teaching her how to humanely handle mice and rats.

Montgomery recently joined the Biodefense Proteomics Group, part of Biosciences' Defense Biology Division. The group supports homeland security and biodefense preparedness by characterizing interactions between a host and pathogens. Her work is part of a greater effort at Livermore to detect, identify, image, and understand pathogens.

The Biosciences group is investigating such pathogens as *Yersinia pestis* and *Bacillus anthracis*, the agents of plague and anthrax, respectively. These agents are of considerable concern to human health from a civilian biodefense perspective. Montgomery's focus is on discovering what proteins are manufactured by *Y. pestis* and determining other biochemical changes that are triggered by the bacterium. In this way, bioscientists may be able to develop a rapid test that would indicate the presence of *Y. pestis* in the body before telltale symptoms occur—and people become infectious.

The group uses mammalian cells and whole human blood to explore host–pathogen interactions. Researchers use two-dimensional gels, chip-based mass spectrometry, and protein arrays for identifying the markers or signatures of pathogen presence.

"I've learned almost everything on the job," Montgomery says, crediting people in Biosciences for making her a full-fledged member of their research effort.

From Games to Physics

It seems fitting that the person overseeing the care and maintenance of the world's most powerful supercomputer wrote his first C program in junior high school. "I've always been into computers," says Adam Bertsch, who studied electronics in high school and left college midway through his studies to work for Sprint, VA Linux Systems, and then Sony Computer Entertainment Corporation in Silicon Valley.

At Sony, Bertsch was systems administrator for a group that created software tools used by developers of the forthcoming Sony PlayStation®3. While there, he heard about job opportunities at Livermore from people he met at California State University at Chico. "I was interested in being on the cutting edge of technology, doing new and exciting stuff," says Bertsch. "I knew that the world's fastest computers come through Livermore, and I'd always have new challenges here."

Bertsch joined the Computation Directorate in 2004, working on the desktop support team. He soon transferred to the Production Linux Group, which he describes as a "young, hip group." As a systems and network associate, he is one of eight systems administrators who support more than 20 high-performance computing systems. These supercomputers, which are part of NNSA's Advanced Simulation and Computing Program, perform enormous calculations to simulate the physics of nuclear weapons for researchers in Livermore's Defense and Nuclear Technologies (DNT) Directorate.

Bertsch is the primary systems administrator for BlueGene/L, the world's most powerful supercomputer. One part of his job is "fighting fires" on the machine. Some problems are transient and do not require action, but others are linked to an occasional hardware failure.

BlueGene/L has 65,536 nodes, each with 2 microprocessors and its own file system of 224 servers providing 1 petabyte of disk space. Inevitably, microprocessors, compute cards (containing 2 nodes), and disk drives fail and must be replaced. (See *S&TR*, April 2005, pp. 23–25.)

While the machine undergoes a long checkout process before being turned over to DNT for classified use, it is available to a few users for unclassified simulations. These early science runs have resulted in important research results. "We've been conducting science on this machine with exciting results," he says.

In 2005, the machine demonstrated its potential when it ran molecular dynamics simulations of tantalum under high pressure. First 16 million atoms were simulated and then 500 million atoms. When Livermore's Multiprogrammatic Capability Resource supercomputer was used to simulate 64,000 atoms, those calculations showed a solid–liquid border that seemed to be ordered. In the higher-resolution simulation on BlueGene/L, however, the boundary appeared to be chaotic.

As systems administrator, Bertsch schedules machine downtimes for maintenance, helps users through the Livermore Computing phone hotline, and writes documentation that describes fixes to problems so other technicians will know what to do should the problem recur. "We do work no one has tried before," says Bertsch. "Most systems administrators can find solutions to problems by using an Internet search engine because someone out there has almost certainly solved the exact problem before. But no one has ever done the things we're doing at Livermore."

Adam Bertsch is the primary systems administrator for BlueGene/L, the world's most powerful supercomputer.

Bertsch is also working with IBM and Livermore experts on planning for two generations of supercomputers beyond BlueGene/L. He has traveled to IBM research and manufacturing facilities in Rochester, Minnesota, and is helping to document requirements for these next-generation systems.

In comparing his experience at Livermore with that of private industry, he says, "The Laboratory's academic environment allows us to focus on what is possible instead of what is profitable." Bertsch is completing his lower division requirements at Los Positas Community College. He plans to use the Laboratory's option to earn a bachelor's degree in computer science from California State University at Chico through video and online instruction. "A huge part of why I came to the Laboratory is that people are so supportive of education," he says.

Looking Ahead

Demand continues to grow for technicians with a broad variety of backgrounds. Technicians with special skills, aptitudes, interests, and experience are essential to the Laboratory's success. Without them, team science would be missing some crucial players.

—Arnie Heller

Key Words: Advanced Simulation and Computing Program, biodefense, BlueGene/L, complementary medicine, High Explosives Application Facility (HEAF), Multiprogrammatic Capability Resource supercomputer, National Ignition Facility, proteomics, University of California Breast Cancer Research Program, *Yersinia pestis.*

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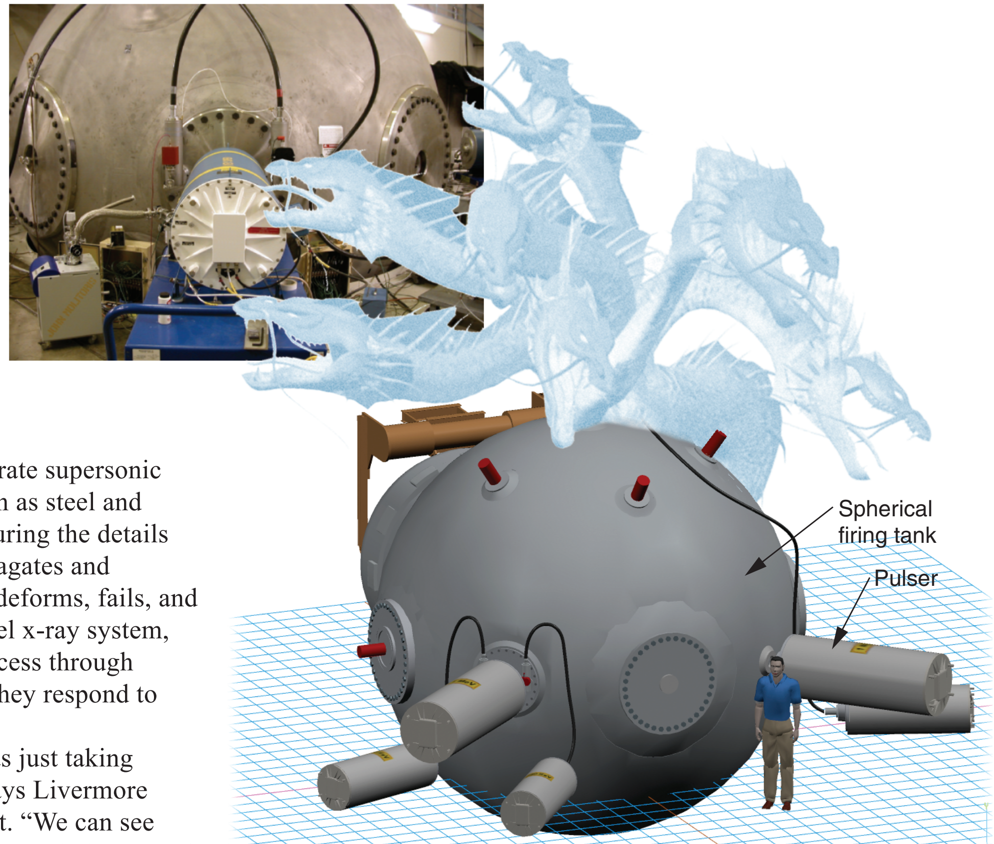
The Shocking Truth about Detonations and Metals



The current configuration of Hydra, Livermore's multichannel x-ray system, has two 1-megaelectronvolt super pulsers, one 450-kiloelectronvolt super pulser, and two 450-kiloelectronvolt pulsers. The fifth channel projects a view that allows scientists to determine if the experiment breaks cylindrical symmetry. The rendering of Hydra shows all five pulsers. Above left is a photo of the system.

WHEN high explosives detonate, they generate supersonic shock waves that can cause materials such as steel and aluminum to deform and ultimately fail. Capturing the details of this dynamic process—how the shock propagates and interacts with materials and how the material deforms, fails, and fragments—is tricky. Livermore's multichannel x-ray system, called Hydra, provides a window into this process through exquisitely detailed radiographs of metals as they respond to detonations and the intense shocks generated.

"People usually think of imaging systems as just taking 'pictures,' but Hydra provides much more," says Livermore physicist John Molitoris, who leads the project. "We can see through to the event of interest, observe density variations, track a process, and measure velocities." Hydra can record a sequence of images, capturing a dynamic process as it evolves over time and showing, for example, how a material responds to intense shock loading. The system can also record multiple images at one time but from various angles, allowing scientists to reconstruct a detailed three-dimensional snapshot at one moment in the process. This approach allows scientists to examine metal fragments as they are produced and ejected from the original component.

With Hydra's radiographs, Livermore researchers now have access to never-before-measured data on the physical characteristics, velocity, deformation history, and fragmentation of shocked metals. They also have discovered features and phenomena not predicted by materials models.

The Many-Headed Hydra

Named for the many-headed monster in Greek mythology, the multichannel system is located in Livermore's High Explosives Applications Facility (HEAF). In its present configuration, Hydra has five x-ray channels that image dynamic experiments inside a 4.9-meter-diameter spherical firing tank. The three channels driven by super pulsers allow Hydra to generate a higher x-ray flux than commercial pulsers, resulting in higher contrast radiographic images over a wider range of material densities. The fourth and fifth channels are driven by standard 450-kiloelectronvolt x-ray pulsers, which will be upgraded to new super pulsers. The fourth channel increases Hydra's time sequence capabilities, and the fifth channel gives a "different view" according to Jan Batteux, lead technical associate for Hydra. "Channel five projects a view that allows us to determine if the experiment is breaking cylindrical symmetry," says Batteux.

Not only can operators change the timing of x-ray flashes, they also can adjust the system's contrast so it images shock processes in various materials from aerogels to steel and possibly even tantalum. Hydra's 25-nanosecond time resolution can "freeze" any shock process caused by detonation. Spatial resolution is better than 1 millimeter and can exceed 0.1 millimeter, depending on the level of contrast.

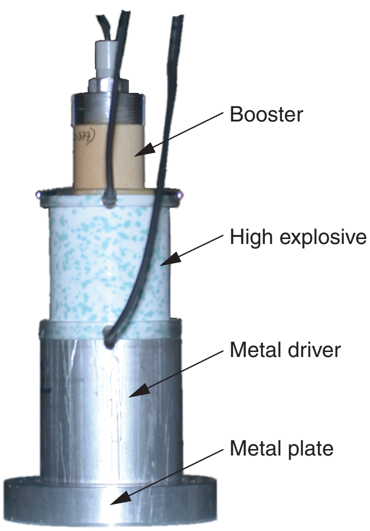
Shock and Spall

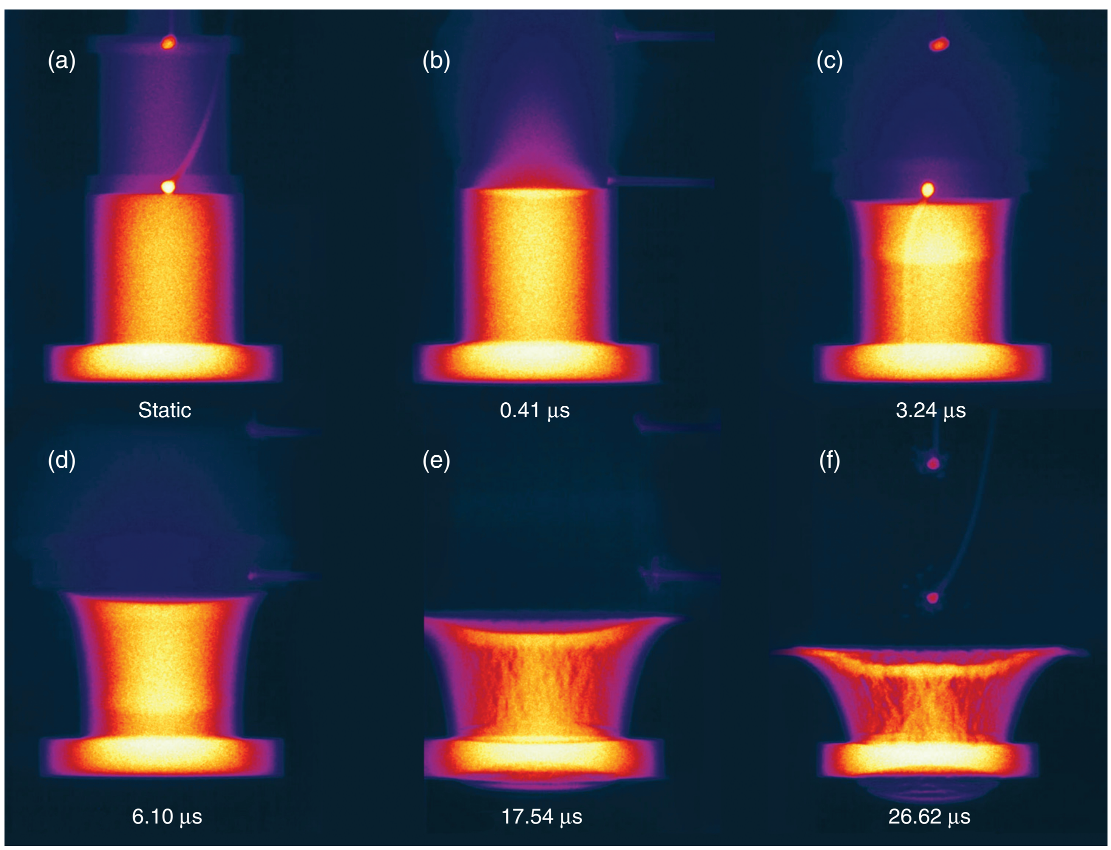
Hydra became operational in summer 2004, and since then, it has provided valuable information for validating computer models. (See *S&TR*, December 2004, pp. 22–25.) Experimental results from Hydra are critical to the model validation effort because the system can precisely measure a material's response and velocities. These detailed results can then be compared to a code's predictions, which show scientists whether a code accurately models the phenomena. "Modern computer simulations generate predictions in vivid detail," says Molitoris, "but to validate and improve the codes, we need diagnostics such as Hydra that can record test data of equal detail."

Livermore scientist Raul Garza and Molitoris designed a series of metal-pushing experiments (MPX) to investigate how bulk metal responds to shock, including the effects of spallation. "Spallation is the prompt ejection of material from the outer surface of a shocked metal," says Garza. When a shock wave hits a metal object, much of it passes through the object. But some of it reflects back and forth from the surfaces, like an echo, causing the metal to spall. Spall especially affects the state of the residual metal and how it finally fragments. The situation is further complicated by the metal chunks or particulates injected into the region being shocked.

In the MPX setup, the detonating explosive main charge imparts a known shock to a solid cylindrical metal driver. The driver delivers the shock to a metal plate, which can spall. The driver's length can be varied to adjust the strength of the shock transmitted to the plate: the longer the driver, the weaker the shock. When the metal plate spalls, it creates a spall disk that is ejected from the bottom. Hydra radiographs capture in detail how the metal plate and driver respond to the shock wave.

"Our goal was to measure the deformation history of the disk, the possible formation of the spallation region, and if spall occurred, the ejection velocity. But we learned much more," says Molitoris. Late-time response of the driver yielded unexpected results. Both deformation and velocity are easily quantified by time-sequence radiography, where a change in position is measured as a function of time. However, the Hydra images showed the response of the *entire* component as a function of time, not just the spall region. The high-resolution time-sequence data clearly showed not only the details of the spallation process but also fragmentation and residual structure of the metal driver. In particular, a conical core section formed in the driver component of the experiment and a pedestal formed at the base of the driver where the shock was transmitted to the spall disk.





The experimental setup of a typical metal-pushing experiment is shown above. The Hydra x-ray images at right show the shock process (in microseconds, µs). Formation of a conical core and pedestal becomes apparent in (e) and (f).

"None of the codes predicted this particular response to the shocks," says Molitoris. "In fact, when we first looked at the images, we didn't believe the driver was breaking up in this manner." Computer colorization added by Livermore scientist Hank Andreski, who also designed Hydra's computer control system, enhanced the structure forming inside the shocked driver.

The next step was to recover the residual pieces of the driver to confirm the radiographic data. In following experiments of the MPX series, the team did, indeed, recover conical cores along with the spall and ejecta disks. "The data gathered from the radiographs allowed us to quantify the way this component fails and breaks up," says Molitoris. "We saw something unexpected and confirmed it, elevating our confidence in Hydra. That's the beauty of high-fidelity experimental data; we get a clear glimpse of the truth. Then, of course, we have to understand it." Understanding a metal's response to high-explosives-generated shock waves is important to work for the Department of Energy and the Department of Defense. Data generated from MPX are helping scientists improve codes used to model shocked metals.

Subsequent metallurgy performed on the recovered pieces showed that the metal forming the pedestal had no voids or rips, but the conical section was clearly a product of violent processes. Metal had ripped away from this section, leaving a jagged brittle cone. According to Molitoris, the cone may be caused by a hydrodynamic backsplash—an effect that is well known in fluid dynamics. In this process, a fluid surface hit by an object (or a drop of liquid) forms a peak in the splash zone, and frequently, a drop of liquid is ejected and falls back to the fluid surface. Some researchers speculate that the peak formed by the backsplash could initiate the formation of the conical core. None of these processes was predicted by the codes.

The Hydra team is also conducting experiments to examine how the type and condition of a metal affects the spallation process. For example, plates of heat-treated steel and brass do not eject whole spallation disks, rather they eject multiple pieces. After spallation, residual metal is very brittle, which significantly changes the final fragmentation process. The team also found that untreated steel and aluminum spall readily, while stainless steel deforms but does not spall under these conditions.

This material recovered from a shocked metals experiment was evident in the Hydra image data. (See image [f] in the figure on p. 12).

Metals under Extreme Conditions

These experiments are improving scientific understanding of how metal behaves under high pressure and shock conditions. "We can now see aspects of dynamic metallurgy that no one has predicted," says Molitoris. "With Hydra, we not only see these details frozen in time, but we also can observe the fragmentation process as it evolves. Such time-sequence detail is not available with other diagnostics." In addition, with Hydra's high temporal and spatial resolution and its time-sequence capabilities, scientists can examine fragments as they form, thus eliminating the tedious and time-consuming process of capturing the fragments for further study.

More improvements are planned for Hydra. Senior radiographer Chuck Cook is working on filmless data acquisition, and the team is examining electronic imaging for some experiments so data can be transferred directly to the computer. The major upgrade for Hydra is expanding the system to 10 or 11 x-ray channels, which will increase the time-sequence imaging capabilities.

"The world of shocked metals is violent, fast, and full of twists and turns," says Molitoris. "Freezing this world so we can examine it is our way of getting a glimpse of the truth."

—Ann Parker

Key Words: aluminum, fragmentation, high explosive, High Explosives Applications Facility (HEAF), Hydra multichannel x-ray system, metal behavior, shock wave, spall, x-radiography.

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Floating into Thin Air

Two wire cables connect the gondola of the High Energy Focusing Telescope (HEFT) to its balloon. By the time the balloon reaches its float altitude (inset) 40 kilometers above Earth's surface, it has expanded enough to fill the space of a football stadium.

ON May 18, 2005, a giant helium balloon carrying the High Energy Focusing Telescope (HEFT) sailed into the spring sky over the deserts of New Mexico. The spindly steel and aluminum gondola that houses the optics, detectors, and other components of the telescope floated for 25 hours after its launch from Fort Sumner, New Mexico. For 21 of those hours, the balloon was nearly 40 kilometers above Earth's surface—almost four times higher than the altitude routinely flown by commercial jet aircraft. In the upper reaches of Earth's atmosphere, HEFT searched the universe for x-ray sources from highly energetic objects such as binary stars, galaxy clusters, and supermassive black holes.

Before landing in Arizona, the telescope observed and imaged a dozen scientific targets by capturing photons emitted from these objects in the high-energy (hard) x-ray range (above 10 kiloelectronvolts). Among these targets were the Crab synchrotron nebula, the black hole Cygnus X-1 (one of the brightest x-ray sources in the sky), and the blazar 3C454.3. The scientific data gathered from these targets are among the first focused hard x-ray images returned from high altitudes.

"It went up, it worked, and it collected data," says Livermore physicist Bill Craig, who is part of the multi-institution collaboration that built and launched the telescope. HEFT is actually an array of co-aligned telescopes that together provide the unique high-sensitivity (sub-arcminute) resolution and few-arcsecond positioning required to achieve its science goals. Each telescope consists of a grazing incidence optics module that focuses onto a shielded solid-state pixel detector. (See *S&TR*, November 2004, pp. 4–11.) In designing HEFT, the collaboration, which includes researchers from Lawrence Livermore, the California Institute of Technology, Columbia University, and the Danish Space Research Institute, capitalized on the special core competencies of each institution. With Laboratory Directed Research and Development funding, the Livermore team engineered HEFT's optics and designed and built the gondola.

Craig is clearly pleased with the success of the flight. "We collected far more information from hard x-ray sources than with our earlier generation of instruments," he says. "A lot of people will be working on the data for years to come."

X Marks the Spot

X-ray telescopy is not new. Coverage of the low-energy (soft) x-ray band (up to 12 kiloelectronvolts)—by missions involving the National Aeronautics and Space Administration's (NASA's) Chandra X-Ray Observatory and the multinational XMM satellite—has been excellent and thorough.

HEFT takes the basic principles of these soft x-ray missions and moves into the 10- to 70-kiloelectronvolt range, where the demands for accuracy and precision in engineering the telescope's optics are much higher. Because of its range and relatively large effective collecting area of about 60 square centimeters, HEFT is well suited for imaging objects such as supernova remnants and galaxy clusters. HEFT is also ideal for detecting objects obscured by galactic dust.

Active galactic nuclei (AGN)—some of the brightest extragalactic x-ray sources—are distant galaxies with massive black holes at their centers. AGN contribute significantly to the x-ray background of the universe, which is of great interest to astrophysicists in studying the origins of the universe. Although AGN have been observed in the soft x-ray band, many of them are obscured by dust clouds that soft x rays cannot penetrate. However, the high-energy particles of these dust-covered AGN can be detected with the hard x-ray focusing apparatus of HEFT.

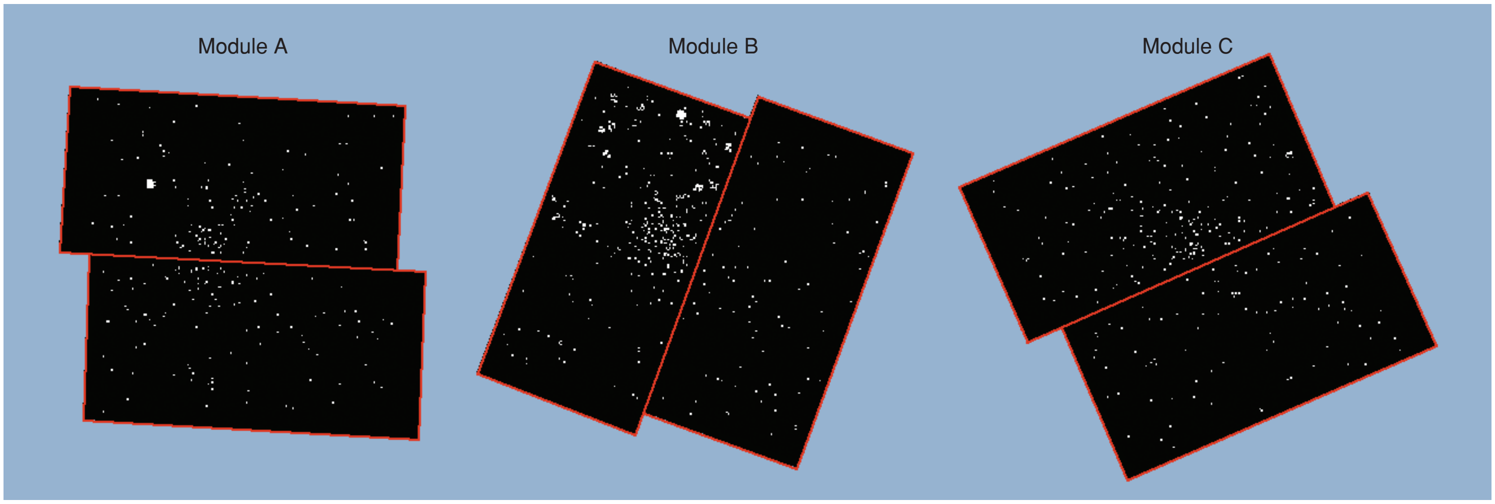
Retrieving large amounts of data from the HEFT mission was not the only great success according to Craig. Despite the expected vagaries of balloon missions, the launch itself went off without a hitch. "Balloon launches are completely unpredictable," says Craig. "We never know what's going to happen."

The balloon, which is made from a material similar to a plastic bag, swells to the size of a football stadium by the time it reaches its float altitude at 40 kilometers. At the time of launch, the helium occupies only the very top of the balloon, giving the balloon a teardrop shape. Once an experiment is completed, explosives are triggered, causing the balloon to rip open. As the gondola drops to Earth, a parachute deploys to aid in the landing. A flight crew follows the landing balloon to recover the gondola and equipment.

Starlight, Star Bright

HEFT spent about 20 hours of its mission focusing on targets. Its detectors needed only a few minutes to confirm the presence of bright sources such as Cygnus X-1 and the Crab. Fainter sources required several hours to confirm detection. HEFT and NASA's Swift x-ray telescope simultaneously observed the extragalactic blazar 3C454.3. Because the blazar was under eruption during the HEFT flight, it was one of the brightest AGN in the sky.

"What we look for in the data is spectral variation," says Craig. "We've got a lot of data to analyze now." The first analysis task, currently under way, is aspect reconstruction to determine the pointing position of the telescope versus time.



HEFT's three high-energy x-ray focusing optics modules recorded these first light images (now being analyzed) of the Crab Nebula. Because this target was extremely bright, the high-energy telescope needed only 5 minutes to record the data.

Out of This World

Craig is eager to keep HEFT afloat. A mission is scheduled for 2007 in Australia, where HEFT's detectors and star trackers will be pointed at the center of the galaxy in the southern sky. Also slated is a launch from Sweden in 2008. On that flight, the balloon will cross the Arctic Circle to Canada at a time when Cassiopeia A will be in HEFT's field of view for five days. Cassiopeia A is a supernova remnant that is thought to be 327 years old.

Plans are already under way to take HEFT to the next level. NASA's Small Explorer Program has approved the Nuclear Spectroscopic Telescope Array (NuSTAR), a follow-on project to HEFT. NuSTAR takes HEFT's x-ray focusing abilities and sends them beyond Earth's atmosphere on a satellite. The optics design and the proposed production process for NuSTAR are based on those used to build the HEFT telescopes. "NuSTAR is opening one of the few remaining frontiers in space," says Craig. "With it, we will be able to bring the high-energy universe into focus."

NuSTAR will be hundreds of times more sensitive than any previous hard x-ray instrument, which will greatly improve image resolution. It will orbit Earth at an altitude of about 480 kilometers for 3 years, during which time researchers intend to take a census of black holes. They hope to measure both the rate at which black holes are growing and the accretion rate at which material has fallen into black holes over time.

Craig underscores the importance of Livermore's contribution to the two missions. "Both NuSTAR and HEFT fit perfectly with Livermore's core competencies in hard x-ray and high-energy astrophysics research," he says. "It's important that we keep flying the HEFT missions—so we can answer some primary research questions and demonstrate what can be done."

—Maurina S. Sherman

Key Words: active galactic nuclei (AGN), balloon launch, black holes, hard x rays, High Energy Focusing Telescope (HEFT), Nuclear Spectroscopic Telescope Array (NuSTAR), soft x rays.

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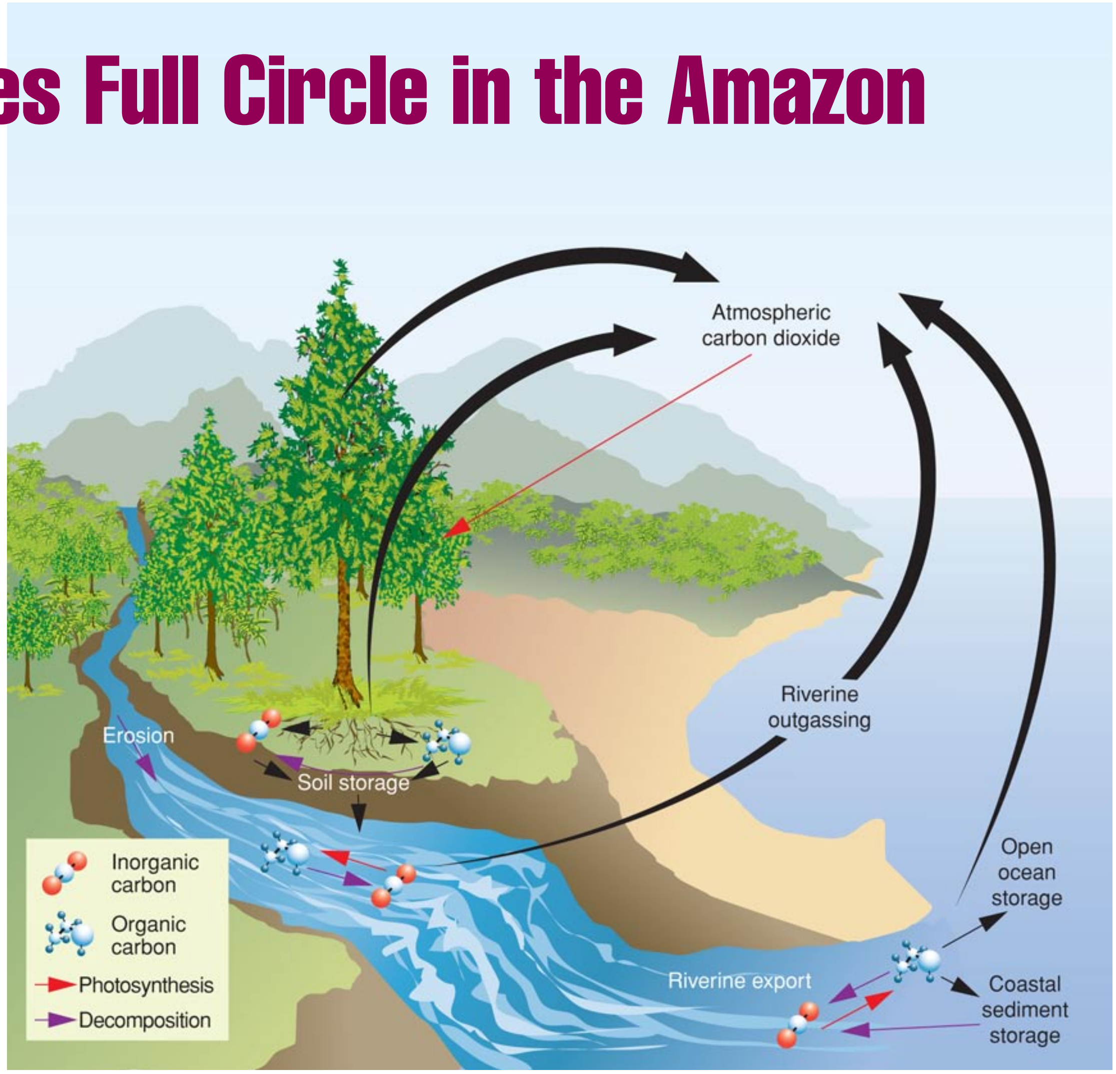
Carbon Goes Full Circle in the Amazon



In Earth's carbon cycle, carbon is exchanged between the planet's land, atmosphere, and oceans. In the process, it is transformed from inorganic carbon to organic carbon and back again.

IN studying Earth's carbon cycle—the exchange of carbon between the planet's land, atmosphere, and oceans—scientists are trying to understand the role played by huge tropical rainforests such as the Amazon River basin. In particular, they want to determine how long an ecosystem stores atmospheric carbon dioxide in its plants, soils, and rivers.

Many scientists hope that such ecosystems might sequester this greenhouse gas, produced in excess by human activities, for decades or even centuries. However, results from a collaboration involving researchers from the University of Washington (UW), the Stroud Water Research Center, Livermore's Center for Accelerator Mass Spectrometry (CAMS), and the University of São Paulo, Brazil, indicate that carbon cycling in the Amazon River basin may be much faster than predicted. Measurements of river water samples showed that the carbon had been stored in the surrounding landscape of the 6.2-million-square-kilometer basin for only about 5 years before being returned to the atmosphere as carbon dioxide.

What Goes around Comes Around

The term carbon cycle describes the complex processes carbon undergoes as it is transformed from organic carbon—the form found in living organisms such as plants and trees—to inorganic carbon and back again. Most of the carbon in rivers originates as atmospheric carbon dioxide and either cycles back to the atmosphere or settles in sediments of the coastal ocean where it is eventually buried.

For example, in the Amazon basin, tropical forests "breathe in" carbon dioxide from the atmosphere and during photosynthesis transform this inorganic carbon into organic carbon. As plants die and decay, they carry carbon into the soil. Decomposition then begins to transform organic carbon back again into inorganic carbon. Rain and groundwater transport carbon from soil, decomposing woody debris, leaf litter, and other organic matter in the waterways, where it is digested by microorganisms, insects, and fish. The carbon dioxide they generate and the dissolved inorganic carbon carried into the rivers from on land then return to the atmosphere.

Determining the sources of carbon in a river, how long it was on land, and when it changed forms are difficult problems because so many plants and soils contribute to the carbon cycle. Previous measurements in the downstream section of the Amazon basin indicated that the carbon there was 40 to more than 1,000 years old. Researchers reasoned that tropical forest regions might sequester carbon for decades or even centuries, thus serving as a potential site for the long-term storage of atmospheric carbon dioxide.

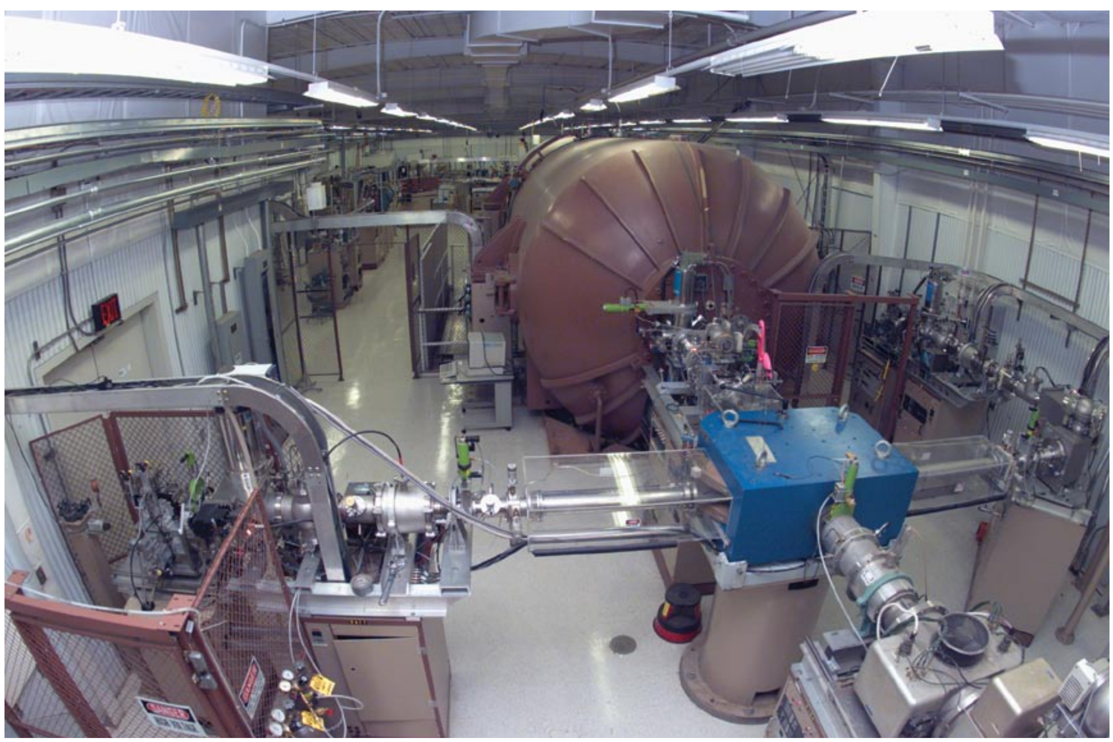
According to Livermore scientist Tom Brown, who worked on the carbon-aging project, such earlier estimates had not included the amount of carbon dioxide returned to the atmosphere by riverine outgassing. Characterizing this carbon dioxide—for example, determining its average age—is an important step if scientists are to accurately determine the amount of carbon being exchanged between the biosphere and the atmosphere in the Amazon River basin.

Taking Stock of Carbon

For the carbon-aging study, the project team, led by UW graduate students Emilio Mayorga and Anthony Aufdenkampe, used samples from the Carbon in the Amazon River Experiment (CAMREX), a long-term collaboration to examine the processes that control the distribution and transformation of water and bioactive elements such as carbon, nitrogen, and oxygen in the Amazon River system. With funding from Livermore's University Relations Program and CAMS, Mayorga and Aufdenkampe worked with Brown and Laboratory postdoctoral researcher Carrie Masiello (now an assistant professor at Rice University) to analyze the river water samples. Using Livermore's accelerator mass spectrometer, they measured the radiocarbon, or carbon-14, in over 150 samples—more than double the number of existing river radiocarbon measurements from that area. According to Mayorga, these measurements represent the largest and most comprehensive radiocarbon data set to date for any river system in the world.

Carbon-14, which has a radioactive half-life of 5,730 years, can be used to determine the rate of carbon exchange between the atmosphere and the oceans and land. Carbon-14 is produced naturally in the atmosphere when cosmic-ray neutrons hit nitrogen-14. The concentration of carbon-14 in atmospheric carbon dioxide remained fairly constant for thousands of years. However, between 1954 and 1963, when atmospheric nuclear tests were conducted, the carbon-14 in the atmosphere doubled. After the tests were halted, the elevated concentrations began to decrease as atmospheric carbon dioxide—which includes the elevated carbon-14 fraction—exchanged carbon into other not-yet-elevated carbon reservoirs in the oceans and on land.

This infiltration of nuclear-test carbon-14 into carbon reservoirs provides scientists with valuable information on carbon exchange. Once they know the rate at which nuclear-testing carbon-14 moves through the carbon cycle, scientists can determine the rate at which human-induced carbon dioxide is absorbed and released, because the same physical rules govern the transfer processes.



The 10-megavolt spectrometer at Livermore's Center for Accelerator Mass Spectrometry is one of the most precise and high-throughput spectrometers in the world.

According to Brown, the CAMS spectrometer is one of only a few in the world that can measure radiocarbon with the precision and throughput required for a project such as the carbon-aging study. In accelerator mass spectrometry, negative ions generated from an ion source are accelerated across a field of millions of volts. The accelerated ions smash through a thin carbon foil that destroys all molecular species and strips the ions of many electrons. After a second stage of acceleration, the ions pass through a high-energy mass spectrometer and finally slow to a stop in a gas ionization detector. The signals obtained from the detector allow scientists to distinguish and count individual carbon-14 ions and determine the ratio of those ions to ions of other carbon isotopes. (See *S&TR,* July/August 2000, pp. 14–19.)

Because of its sensitivity, the CAMS spectrometer allows scientists to measure concentrations of isotopes in samples less than 1 milligram and the relative abundance of isotopes at very low levels. It can, for example, find one carbon-14 atom among a thousand billion (10^{15}) other carbon atoms.

In the Amazon basin study, the project team determined a sample's age by comparing its carbon-14 concentration to atmospheric concentrations over the last 40 years. The team's comparisons showed that in most of the Amazon samples the carbon-14 was only slightly higher than the atmospheric concentration at the time the samples were taken. That is, the level of carbon-14 in most Amazon samples corresponded to the atmospheric level about 5 years prior to the sampling.

To clarify the data on carbon aging, the project team also analyzed the carbon-13 abundance in the Amazon samples. The basin's rivers receive significant drainage from high-elevation areas, which are formed of very old carbonate rock. The amount of dissolved carbon dioxide from carbonate rock may affect the measurements because the carbon-14 concentration in these old formations is essentially zero.

Carbon-13 is a stable isotope, and its concentration in a sample is not affected by radioactive decay. Other processes, however, influence the carbon-13 concentration in a sample during its formation. For instance, carbonate rocks generally have carbon-13 concentrations about 25 parts per thousand higher than trees, and most grass plants have carbon-13 concentrations about 10 parts per thousand higher than trees. By comparing the abundance of carbon-14 and carbon-13 in the Amazon basin samples, the project team could account for these influences on the apparent carbon-14 ages of affected samples. These measurements indicated that carbon from the carbonate rock was flushed from the water into the atmosphere as it flowed downstream. By the time the water reached the lowlands, most of the carbon had returned to the atmosphere.

Balancing the Carbon Budget

"This detailed study of the Amazon basin gives us a clearer picture of the role played by streams and rivers in the carbon cycles of tropical regions," says Brown. Most of the atmospheric carbon dioxide taken up by the Amazon basin in a given year is not sequestered for decades to centuries but, rather, is returned to the atmosphere as carbon dioxide on a time scale of 5 years. The study also provides information for researching how land use may affect climate. By more precisely measuring the carbon cycle in the Amazon basin, the project team has taken another step in helping scientists understand how atmospheric carbon dioxide concentrations affect the global carbon cycle and the world.

—Ann Parker

Key Words: Amazon River basin, carbon-14, carbon cycle, carbon dioxide, Center for Accelerator Mass Spectrometry (CAMS), radiocarbon dating, sequestration.

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Each month in this space, we report on the patents issued to and/or the awards received by Laboratory employees. Our goal is to showcase the distinguished scientific and technical achievements of our employees as well as to indicate the scale and scope of the work done at the Laboratory.

Patents

Aerodynamic Drag Reduction Apparatus for Wheeled Vehicles in Ground Effect

Jason M. Ortega, Kambiz Salari
U.S. Patent 6,974,178 B2
December 13, 2005
An apparatus for reducing the aerodynamic drag of a wheeled vehicle in a flow stream. The vehicle has a wheel assembly supporting its body. The apparatus includes a baffle assembly adapted to a position upstream of the wheel assembly for deflecting airflow away from the wheel assembly so as to reduce incident pressure on the wheel assembly.

Compact Imaging Spectrometer Utilizing Immersed Gratings

Scott A. Lerner
U.S. Patent 6,977,727 B2
December 20, 2005
A compact imaging spectrometer composed of an entrance slit for directing light; a lens means for receiving, refracting, and focusing the light; an immersed diffraction grating that receives the light from the lens means and defracts the light back to the lens means; and a detector that receives the light from the lens means.

Apparatus and Method for Reducing Drag of a Bluff Body in Ground Effect Using Counter-Rotating Vortex Pairs

Jason M. Ortega, Kambiz Sabari
U.S. Patent 6,979,049 B2
December 27, 2005
An aerodynamic-based drag reduction apparatus and method for bluff bodies, such as tractor-trailer trucks, uses a pair of lift surfaces extending to lift surface tips and located alongside the bluff body, for example, on the opposing left- and right-side surfaces. In a flow stream substantially parallel to the longitudinal centerline of the bluff body, the pair of lift surfaces generates a pair of counterrotating trailing vortices that join in the wake of the bluff body in a direction orthogonal to the flow stream. The confluence draws or turns the flow stream in and around behind the trailing end of the bluff body, raising the pressure on a base surface at the trailing end and thereby reducing the aerodynamic base drag.

Compact Catadioptric Imaging Spectrometer Utilizing Reflective Grating

Scott A. Lerner
U.S. Patent 6,980,295 B2
December 27, 2005
An imaging spectrometer apparatus composed of an entrance slit for directing light, a light means for receiving the light and directing the light, a grating for receiving the light from the light means and defracting the light back onto the light means which focuses the light, and a detector for receiving the focused light. In one embodiment, the light means is a rotationally symmetric ZNSE aspheric lens. In another embodiment, the light means is composed of two ZNSE aspheric lenses that are coaxial. In a third embodiment, the light means is composed of an aspheric mirror and a ZNSE aspheric lens.

Awards

A team of scientists led by Laboratory physicist **Fred Streitz** received the **2005 Gordon Bell Prize** for pioneering materials science simulations conducted on the world's fastest supercomputer—the IBM BlueGene/L at Livermore. Other team members included **James Glosli**, **Mehul Patel**, **Bor Chan**, **Robert Yates,** and **Bronis de Supinski** of Livermore, and James Sexton and John Gunnels of IBM. The title of their entry was "100+ Tflop/s Solidification Simulations on BlueGene/L." Running a three-dimensional molecular dynamics code on BlueGene/L, the team investigated solidification in tantalum and uranium at extreme temperatures and pressures with simulations ranging from 64,000 atoms to 524 million atoms.

Named for C. Gordon Bell, one of the founders of supercomputing, the prestigious Gordon Bell Prize is awarded to innovators who advance high-performance computing. Bell established the prize in 1987 to encourage innovation that would further develop parallel processing—the computer design philosophy that has driven high-performance computing since the 1980s. The prize, one of the most coveted awards in high-performance computing, is administered by the **Institute of Electrical and Electronics Engineering**.

These People Make Things Happen

The Laboratory's namesake, Ernest O. Lawrence, pioneered the concept of team science, in which experts from different disciplines combine efforts to tackle challenging problems in science and national security. For nearly every Livermore research effort, there is a group of people known as technicians, technical specialists, scientific associates, and other terms. These men and women comprise more than 20 percent of Lawrence Livermore's workforce of 8,000. Technicians, or techs, typically have an associate's or bachelor's degree and work alongside scientists with more advanced degrees. Techs contribute significantly to Livermore's atmosphere of "passion for mission" and technical innovation. In their various assignments, they accumulate a wealth of knowledge about how to build a part, run an experiment, design an instrument, or calibrate a device—skills that often come from experience outside formal education.

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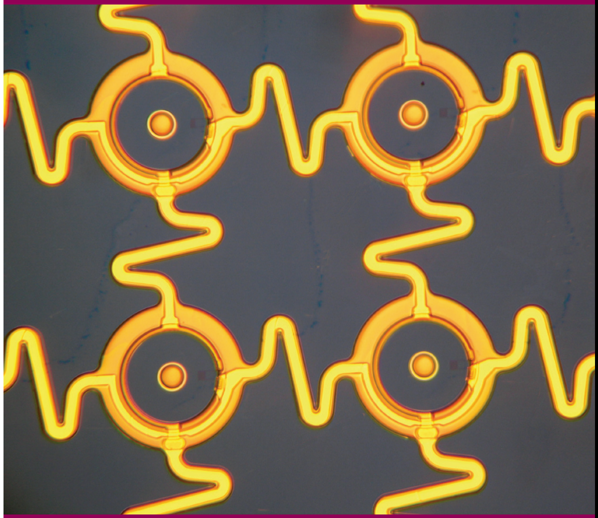
Revolutionary Stress Sensors



Tiny sensors will allow researchers to measure loads in weapons systems for the first time.

Also in April

- *Transparent ceramics offer clear advantages for solid-state lasers.*

- *Livermore materials scientists are using three-dimensional image correlation to better understand the behavior of single crystals.*

- *A Livermore–Los Alamos collaboration successfully tested key components for the Los Alamos DARHT—an accelerator for producing intense x rays for flash radiography.*

Coming Next Month

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